From the Society for Clinical Vascular Surgery

Comparison of the efficacy of upper arm transposed arteriovenous fistulae and upper arm prosthetic grafts

Karen Woo, MD,[a] **Gheorghe Doros, PhD,**[b] **Tina Ng, MD,**[c] and **Alik Farber, MD,**[d] *La Jolla, Calif; Boston, Mass; and Los Angeles, Calif*

Purpose: **Direct comparison of transposed arteriovenous fistulas (tAVF) and arteriovenous grafts (AVG) has been hampered by inherent differences in patient characteristics between tAVF and AVG groups. In this study, using matching to control patient variables, we evaluated our outcomes with upper arm tAVF and upper arm prosthetic AVG.**
Methods: **A retrospective review of all newly created upper arm tAVF and AVG was performed. One hundred ninety upper arm tAVF were group matched for age, gender, race, diabetes, and history of previous failed access with 168 AVG chosen from a pool of 476 concurrently performed AVG procedures. Complication, patency, and intervention rates were compared using multivariate analysis.**
Results: **Mean follow up for our cohort was 29.1 months. Transposed fistulae consisted of 119 basilic vein and 71 cephalic vein transpositions, which were found to have similar demographic parameters, complication rates, and patency rates. There were no differences in 30 day mortality, 24 hour thrombosis, bleeding requiring exploration, or ischemic steal requiring intervention between the tAVF and AVG groups. More AVG developed infection requiring operative exploration than tAVF (7.9% vs 1.6%, respectively. $P = .004$). Primary patency for tAVF was higher than for AVG: 48% vs 14% at five years ($P < .0001$). Secondary patency rate for tAVF was also higher than for AVG: 57% vs 19% at five years ($P < .0001$). Nine percent of tAVF compared with 53% of AVG required one or more surgical and/or percutaneous revisions to maintain secondary patency ($P < .0001$). Multivariate analysis revealed that utilization of a tAVF was associated with a reduced risk of primary (Hazard Ratio [HR] 0.47, 95% Confidence Interval [CI] 0.35-0.64, $P < .0001$) and secondary failure (HR 0.59, 95% CI 0.42-0.81, $P = .0001$).**
Conclusions: **Transposed arteriovenous fistulas have significantly higher primary and secondary patency rates, require fewer revisions, and are less likely to develop a significant infection than AVG. This study supports the contention that as long as a patient is a candidate for a tAVF based on anatomic criteria, a tAVF should be considered before an AVG. (J Vasc Surg 2009;50:1405-11.)**

When permanent hemodialysis access is needed placement of the radiocephalic arteriovenous fistula (AVF) is usually considered first.[1-4] The forearm cephalic veins, however, are often not suitable for AVF creation due to small diameter, thrombosis, or stenosis caused by repeated venipuncture. Although an antecubital brachial-cephalic AVF is recommended when a wrist AVF is not feasible,[4] presence of venipuncture related cephalic vein stenosis and thrombosis at the antecubital fossa may, likewise, hinder the construction of this type of fistula.[1] According to the National Kidney Foundation Kidney Disease Outcomes Quality Initiative (KDOQI) Vascular Access Guidelines, if construction of a wrist or elbow AVF is not possible, a brachial basilic vein AVF or basilic vein transposition (BVT) is preferred; prosthetic arteriovenous graft (AVG), however, may also be acceptable.[4]

Transposed upper arm arteriovenous fistulas (tAVF) such as BVT and cephalic vein transposition (CVT) have been described in patients who are not candidates for forearm native AVF.[5-7] Although there are a number of reports describing excellent patency of BVT,[7-12] there are some studies that report equivocal results.[13,14] A recent report of 185 patients demonstrated relatively low, equivalent patencies between transposed brachiobasilic AVF and prosthetic brachioaxillary access grafts.[15]

Outcomes of studies comparing tAVF and AVG are often difficult to interpret due to differences in patient characteristics, such as age, gender, and race that exist between these two groups.[11,16-19] Older age, female gender, and African-American (AA) race have been found to be independent risk factors associated with decreased AVF prevalence[1,20,21] and may affect outcomes. Previous studies have controlled for these systematic differences in background characteristics between the two groups using regression techniques (eg, Cox regression, linear, or logistic regressions); however, these methods of controlling are efficient as long as model assumptions are correct. In order

From the Divison of Vascular Surgery, Scripps Green Hospital,[a] the Department of Biostatistics, Boston University School of Public Health,[b] the Department of Surgery, Cedars Sinai Medical Center,[c] and the Section of Vascular and Endovascular Surgery, Boston Medical Center.[d]
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Reprint requests: Alik Farber, MD, Section of Vascular and Endovascular Surgery, Boston Medical Center, C-500, 88 E. Newton St., Boston MA 02118 (e-mail: af1066@gmail.com).
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to more accurately assess outcomes between tAVF and AVG, we chose to control for the confounding differences that typically exist in patient populations undergoing these procedures by comparing case matched cohorts undergoing tAVF or AVG placement.

METHODS

We retrospectively evaluated all upper arm tAVF and upper arm, brachial artery-axillary vein, straight configuration, prosthetic AVG performed at Cedars-Sinai Medical Center in Los Angeles, California between January 1998 and September 2004. The fistula group consisted of upper arm BVT and CVT procedures and has been described previously.[7] This tAVF group included patients who had previous access construction in the ipsilateral as well as the contralateral upper extremity.

The tAVF group was matched for age, gender, race, diabetes, and history of previous failed access with a group of AVG chosen from a pool of concurrently performed AVG procedures. These chosen factors have been found to be associated with outcomes and thus likely confound the fistula and graft comparison.[7,11,16-19] Only primary upper arm AVG were included for evaluation; there were no previous access procedures performed in the ipsilateral upper extremity of the AVG patients.

Office, hospital, and electronic charts were reviewed after Institutional Review Board exemption status was granted. Co-morbid conditions were noted and graded according to the recommended reporting standards.[22]

All patients underwent preoperative noninvasive vascular evaluation that included brachial pressures and waveforms, Allen's test, and brachial/radial artery diameter measurements. Vein mapping was routinely performed to outline and define the size and quality of basilic and cephalic veins.[7] If the vein in question had a stenosis, and the patient had another vein that was suitable for construction of AVF, we preferentially used the optimal vein.

In our practice, we attempted to first place a wrist radiocephalic fistula if anatomically favorable. From there, we moved to a simple brachiocephalic fistula at the antecubital fossa. If this was not feasible, we placed either an upper arm AVG or an upper arm tAVF. The forearm transposed fistula or loop forearm grafts were rarely used and were not included in this series.

The decision to construct an upper arm tAVF was based, in general, on the presence of adequate arterial inflow into the arm, upper arm vein diameter ≥2.5 mm and absence of suitable forearm site for an autogenous fistula. If upper arm cephalic vein was judged adequate on duplex evaluation and superficial on tourniquet-aided examination by the surgeon, an antecubital non-transposed brachiocephalic fistula was constructed. Otherwise, either an upper arm BVT or CVT was placed. The larger of the two upper arm veins, as measured by duplex, was used preferentially. We were liberal to transpose the cephalic vein if it was not easily palpable on tourniquet-assisted physical examination. Patients who were judged not to be candidates for a native AVF underwent placement of an upper arm, straight configuration, 6 mm polytetrafluoroethylene (PTFE) AVG (WL Gore and Associates Inc, Phoenix, Arizona, USA and Bard Inc, Tempe, Arizona, USA). No looped arm, or tapered AVG were utilized. Ultimately, the decision of type of access was determined by surgeon preference.

Operative details are described in Appendix I (online only).

Perioperative and postoperative complications were followed and recorded by the operative surgeon. Complications were graded according to the recommended standards for reports dealing with arteriovenous hemodialysis access procedures. The complications followed were: grade 2 wound infection (requiring operative exploration or removal of access), grade 3 (severe) steal (requiring mandatory intervention), grade 3 postoperative hemorrhage (necessitating return to the operating room) and fistula thrombosis within 24 hours.[22] Grade 3 steal was treated either with fistula banding or the Distal Revascularization Interval Ligation procedure. Thirty-day mortality rate was calculated.

A follow up visit with the vascular surgeon was scheduled during the first month after discharge for suture removal and at that time fistula patency was assessed by physical examination. Transposed AVF were allowed to mature for a minimum of eight weeks and the decision when to use the access for the first time was made either by the attending surgeon or nephrologist. Grafts were typically accessed for dialysis 10 to 14 days after implantation.

No routine surveillance was performed. Non-invasive imaging was used in the initial evaluation of a malfunctioning access. A fistulagram was performed only when symptomatic fistula or graft stenosis were suspected. This was done when intra-access flow was less than 600 cc/min and static or dynamic venous pressures were high. In addition, elevated access recirculation also prompted referral for fistulography. Invasive imaging was not routinely performed for asymptomatic stenosis.

When a prosthetic access occluded, it was reopened using either mechanical or surgical thrombectomy. If mechanical thrombectomy was used, balloon angioplasty of any identified stenosis was attempted. If surgical thrombectomy was used, surgical repair of the underlying lesion was attempted. Occluded tAVF were either abandoned or reopened using mechanical thrombectomy. In the latter case, percutaneous angioplasty or surgical revision was attempted.

For each tAVF record a matched AVG record (matched for age, gender, race, diabetes, and history of previous failed access) was sought from a pool of 476 concurrently performed AVG procedures. For matching, age was operationalized as a categorical variable with categories: (1) less than 40, (2) between 40 and 60, (3) between 60 and 80, and (4) greater than 80.

Statistical analysis was performed using the Statistical Analysis System (SAS Institute Inc., Cary, NC). Summary results for were presented as mean ± standard deviation continuous variables and as frequency (percent) for categorical variables. Two-group comparisons were assessed by the independent samples *t* test or the Wilcoxon rank sum test, as appropriate of continuous variables and by chi-squared test or Fisher's exact test for categorical variables. Fistula and graft patency and limb abandonment rates at each time point were calculated by the life table method as outlined by the Society of Vascular Surgery Ad Hoc Committee on Reporting Standards.[22] Survival differences were tested with the Log rank test.

Primary patency was defined as time of access placement until first thrombosis or any intervention designed to maintain patency.[22] Follow-up for primary patency rate calculations ended when the graft was confirmed to require intervention, thrombosed, or last known to be patent (whichever was shorter). Placement of a dialysis catheter in a patient with a presumably functioning graft, death, or kidney transplantation was an additional endpoint for termination of patency. Secondary patency was defined as the interval from the time of access placement until access abandonment.[22] Secondary patency rate calculations ended when the patient had a new surgical dialysis access placed. The placement of a new dialysis access was used as a surrogate for access abandonment. Although placement of a new dialysis access did not occur at the exact point of access abandonment, placement of a new dialysis access generally occurred within one to two months of access abandonment.

Bivariate analysis was performed. Multivariate Cox proportional hazard models were then evaluated to assess association of variables analyzed in the bivariate analysis and type of surgery (AVG vs. tAVF) on the hazard of primary or secondary access failure while controlling for other independent predictor variables. To search for a final model we used the stepwise selection.

RESULTS

During the 6.5 year study period, 190 upper arm tAVF were constructed in 190 patients. There were 119 BVT and 71 CVT procedures. Four hundred seventy six concurrently performed primary upper arm AVG were identified. Out of the AVG cohort, 168 AVG performed in 168 patients were matched with the tAVF cohort with respect to age, gender, race, diabetes, and history of previous failed access. There was no significant difference in the age, gender, race, history of previous access and diabetes between the tAVF and AVG cohorts (Table I).

There was no significant difference in the thirty day mortality, 24 hour thrombosis, grade 3 postoperative hemorrhage or grade 3 steal between the two groups (Table II). There were significantly more grade 2 infections requiring operative exploration in the AVG group; 7.9% vs 1.6% ($P =$ .004).

Mean follow up for the tAVF and AVG cohorts were 27.1 and 31.4 months, respectively ($P =$ .071). The primary patency at one and five years for the tAVF cohort was 65% and 48%, and for the AVG cohort was 42% and 14%, ($P <$ .001) (Fig 1, Appendix 2, online only). The secondary patency at one and five years for the tAVF cohort was 72% and 57% and for the AVG cohort was 67% and 19% ($P <$ .001) (Fig 2, Appendix 3, online only).

Four surgical and 22 endovascular revisions were required in the tAVF group to maintain secondary patency. In the AVG group, 120 surgical and 127 endovascular revisions were required to maintain secondary patency ($P <$ .001). Among the tAVF procedures, 9% required one or more revisions to maintain secondary patency, compared with 53% in the AVG group ($P <$ .001).

Bivariate analysis showed that history of previous upper extremity access increased the risk of primary failure and secondary failure (Tables III and IV). In bivariate analysis, male gender decreased the risk of secondary failure (Table IV). Multivariate analysis showed that presence of tAVF decreased the risk for primary (Hazard Ratio [HR] .47, 95% Confidence Interval [CI] .35 to .64, $P <$ .001) and secondary failure (HR .57, 95% CI .41 to .78, $P <$ .001). History of previous access increased the risk of primary (HR 1.61, 95% CI 1.17 to 2.2, $P =$ .003) and secondary failure (HR 1.67, 95% CI 1.19 to 2.35, $P =$ .003).

DISCUSSION

Long term hemodialysis access includes native AVF and prosthetic AVG. In the mid 1990s, only 20% of patients in the United States were dialyzing with native fistulas.[23] Because of data illustrating superior patency of native AVF, the National Kidney Foundation Kidney Disease Outcome and Quality Initiative (KDOQI) recommended, among other things, that native fistulas should be constructed in at least 50% of permanent hemodialysis access procedures.[3,4,24]

Table I. Patient characteristics according to access type

	tAVF (%)	*AVG (%)*	P *value*
Age			
≤40	26 (13.7)	16 (9.7)	.356
(40,60)	51 (26.8)	36 (21.8)	
(60,80)	79 (41.6)	78 (47.3)	
>80	34 (17.9)	35 (21.2)	
Male gender	120 (63)	88 (53)	.061
AA race	47 (25)	28 (29)	.355
Diabetes (grade 1-3)	97 (51)	74 (45)	.243
Previous UE access	37 (19)	45 (27)	.082

AA, African-American; *AVG,* arteriovenous grafts; *SD,* standard deviation; *tAVF,* transposed arteriovenous fistulas; *UE,* upper extremity.

Table II. Mortality and complications according to access type

	tAVF (%)	*AVG (%)*	*OR (95% CI)*	P *value*
30 day mortality	5 (2.6)	5 (3.0)	0.86 (0.25,3.04)	.821
Infection (grade 2)	3 (1.6)	13 (7.9)	0.19 (0.05,3.04)	.004
24 hour thrombosis	1 (0.5)	2 (1.2)	0.43 (0.04,480)	.481
Bleeding (grade 3)	7 (3.7)	3 (1.8)	2.07 (0.53,8.12)	.289
Steal (grade 3)	6 (3.2)	8 (4.9)	0.64 (0.22,1.88)	.414

AVG, Arteriovenous grafts; *OR,* odds ratio; *tAVF,* transposed arteriovenous fistulas.

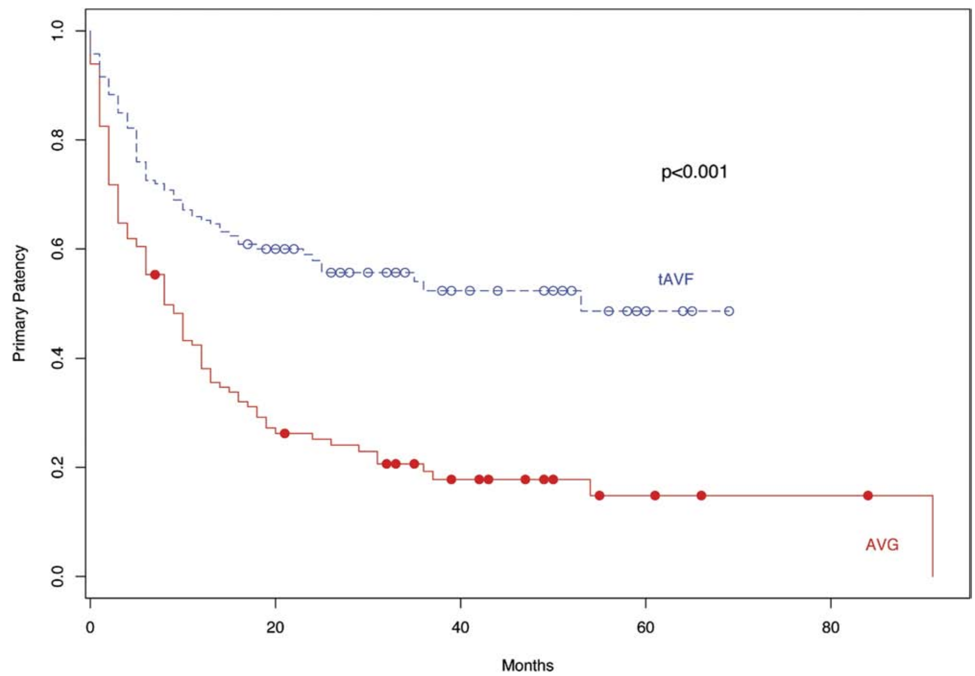

Fig 1. Primary patency of tAVF and AVG. *AA*, African-American.

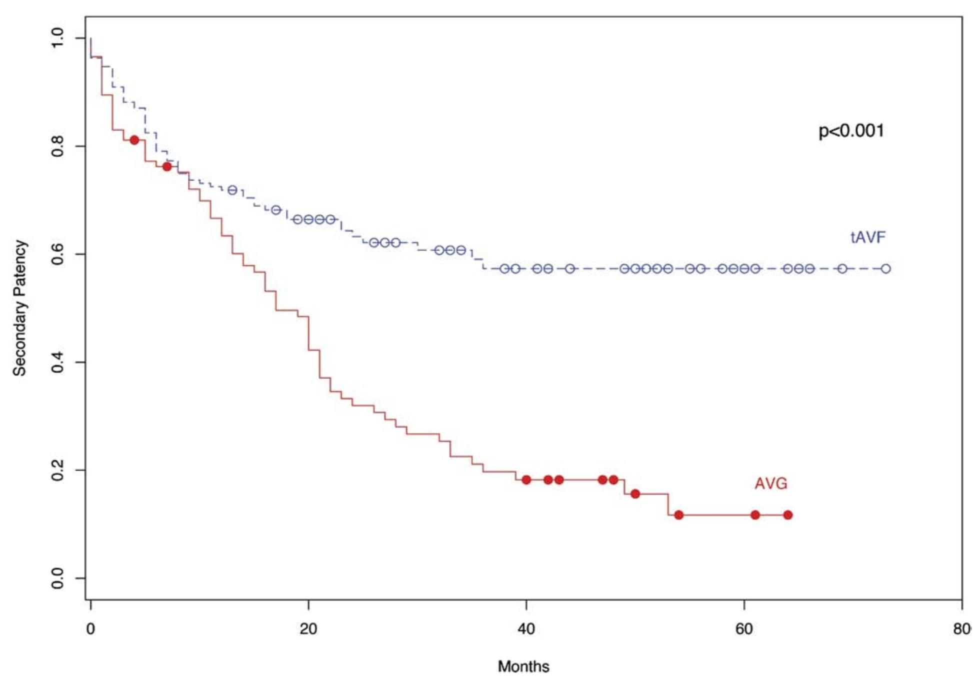

Fig 2. Secondary patency of tAVF and AVG. *AA*, African-American.

The recently created Fistula First Initiative further encourages use of native fistulas by providing physicians with an algorithm designed to optimize care of patients with end stage renal disease (ESRD).[24] Despite these recommendations, the prevalence of native arteriovenous fistula use was only 36% in 2004.[24]

Twenty to thirty years ago, patient selection for dialysis was relatively stringent and most patients were young, non-diabetic men whose veins were well suited for construction of native arteriovenous fistula at the wrist. In recent years, liberalization of selection criteria for dialysis in the United States has led to inclusion of patients who are

Table III. Association of risk factors with primary patency

Print data set WORK.P1 variable	*Hazard ratio*	*95% lower confidence limit for hazard ratio*	*95% upper confidence limit for hazard ratio*	P *value*
Race				
Caucasian	0.891	0.558	1.424	.6296
AA	1.261	0.764	2.079	.3641
Other	1			
Age				
≤40	1.134	0.644	1.998	.6623
(40,60)	1.174	0.734	1.879	.5035
(60,80)	1.335	0.874	2.041	.1817
<80	1			
Diabetes				
No	1.077	0.807	1.438	.6151
Yes	1			
Gender				
Male	0.742	0.556	0.990	.0423
Female	1			
Previous access				
No	0.522	0.384	0.711	<.0001
Yes	1			

Table IV. Association of risk factors with secondary patency

Print data set WORK.P1 variable	*Hazard ratio*	*95% lower confidence limit for hazard ratio*	*95% upper confidence limit for hazard ratio*	P *value*
Race				
Caucasian	1.392	0.763	2.540	.2804
AA	1.745	0.926	3.288	.0850
Other	1			
Age				
≤40	1.229	0.669	2.258	.5059
(40,60)	1.016	0.599	1.726	.9524
(60,80)	1.263	0.793	2.011	.3257
<80	1			
Diabetes				
No	1.065	0.776	1.462	.6956
Yes	1			
Gender				
Male	0.702	0.511	0.963	.0281
Female	1			
Previous access				
No	0.519	0.371	0.725	.0001
Yes	1			

older, more likely to be female, more likely to have peripheral vascular disease, and less likely to have preserved forearm veins. Increasing complexity of patients with ESRD has increasingly been associated with clinical scenarios where wrist or simple antecubital fistula construction is not possible. Efforts to limit the use of prosthetic AVG in these clinical settings led to increased utilization of tAVF for dialysis access.

Both BVT and CVT have been used extensively and have been shown to have similar patency rates.[7] Despite excellent outcomes found by some,[7,10,11] others describe relatively poor tAVF patency rates.[13,25] These differences mainly stem from variability in maturation rates of native arteriovenous fistulas.[26] Variable outcomes of tAVF has resulted in continued utilization of AVG even when tAVF construction was possible.[7]

There have been a number of studies that compared outcomes of tAVF and AVG.[7,11,16,27,28] Many of these studies have been hampered by differences that exist between patients offered native fistulas and grafts.[11,16-19] It has been demonstrated that there are a variety of patient factors that influence the prevalence of fistula creation.[1] Female gender has been repeatedly shown to be a strong predictor of AVG use.[1,20,29,30] Similarly, a number of studies have demonstrated that AVF are used less commonly in African-Americans.[16,29] Increased age[20,29] and presence of diabetes[20] have also been associated with decreased prevalence of fistula use. Furthermore, age,[13,19,31] diabetes,[1,10,32] female gender,[1,33] and history of previous failed dialysis access[7,28,34] have been shown to predict access failure. In order to limit the effect of these confounding factors on outcomes, we performed case matching of our tAVF and AVG groups to control for age, gender, race, diabetes, and history of previous failed access and then used multivariate regression techniques to assess outcome differences between the two procedures. Matching followed by regression has been described to be superior to either method alone.[35]

In our study, the tAVF cohort had a significantly higher primary and secondary patency rates compared with the AVG group. This finding is supported by some,[11,27] but not all series.[16,28] A recent report from the United Kingdom directly compared BVT and brachioaxillary AVG in two groups that were well matched for age, gender, ethnicity, diabetes, and number of prior access procedures.[15] The authors found no significant differences in secondary patency between the two procedures. One potential explanation for these findings is that the one year secondary patency of BVT in this series was only 56.4%, and thereby significantly lower than our 72% tAVF secondary patency. The patency of tAVF in our study is furthermore higher than that of another recent series of tAVF where one-year primary and secondary patency rates were 23% and 47%, respectively.[25]

In addition to low primary patency rates, patients in the AVG cohort required significantly more endovascular and operative interventions to maintain secondary patency. Other authors have also noted increased intervention rates in patients who dialyze through prosthetic grafts.[11,16,36,37] In a recent study, equivalent secondary patency of BVT and brachial artery-axillary vein polyetherurethaneurea (Vectra, Bard Inc, Tempe, Arizona, USA) grafts were reported.[38] However, to achieve this, significantly more thrombectomy and angioplasty procedures were performed in failing grafts compared with BVT fistulas.

With respect to complications, there were significantly more infections requiring removal of the access in the AVG group. This is consistent with other reports.[15,37,38] There was no difference between the groups with respect to bleeding requiring operative intervention or steal requiring operative intervention.

In the multivariate analysis, the most significant factor contributing to improved primary and secondary patency was use of tAVF. History of previous failed dialysis access was another factor that adversely influenced primary and secondary patency. This finding has been demonstrated by other authors[28,34] and may be related to yet undefined patient factors such as propensity to intimal hyperplasia. Age, gender, and diabetes did not exert an effect on patency in our or other series.[15,38]

We compared outcomes of tAVF and AVG in a group of patients well matched for the demographic factors that may have confound results of others. This case matching strengthens the validity of our finding. Nevertheless, our study is not without limitations. The retrospective nature of our series allows for introduction of bias and confounding variables that may affect our conclusions. For instance, the exact reason behind the choice to perform a given operation was not known and therefore surgeon bias could not be well controlled. There were likely anatomical differences in these patients such as vein quality and diameter which affected whether or not tAVF or AVG were chosen. In addition, because the time that first dialysis was initiated through the fistula was not available to us, true fistula non-maturation rates are unknown. We do make the observation that at three and six months the primary patency for the tAVF group was 88% and 76%, respectively. Our practice pattern was such that those fistulas that failed to mature after three to four months were referred for new access placement. Therefore, an assumption can be made that our fistula non-maturation rate was between 12% and 24%. Lastly, there may have been other factors that could have been controlled to allow for a more precise comparison between groups.

In our case matched series, we found upper arm tAVF to have significantly higher patency rates, lower intervention rates, and lower serious infection rates than upper arm brachial artery-axillary vein straight PTFE AVG. It is our conclusion that if a patient is a candidate for an upper arm tAVF based on anatomical criteria he should always be offered that procedure in lieu of a prosthetic graft.

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AUTHOR CONTRIBUTIONS

Conception and design: KW, AF
Analysis and interpretation: KW, GD, TN, AF
Data collection: KW, TN
Writing the article: KW, GD, AF
Critical revision of the article: KW, GD, TN, AF
Final approval of the article: KW, GD, TN, AF
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Appendix 1 (online only). Operative technique

In the operating room, the majority of procedures were performed under local anesthesia with sedation. For patients who did not tolerate local anesthesia, general anesthesia was required. The basilic or cephalic vein was exposed and dissected from 1-2 cm distal to the antecubital fossa to the proximal axilla or shoulder, respectively. All branches were controlled with silk suture and the vein was divided distally. The brachial artery was then exposed immediately proximal to the antecubital fossa and the vein was tunneled superficially to lie next to the brachial artery. In most cephalic vein transposition (CVT) procedures, the brachial artery was exposed through a separate, medial antecubital incision. After administration of systemic or local heparin, an end to side anastomosis was constructed between the transposed vein and brachial artery. The use of systemic heparin was based on surgeon preference. When systemic heparin was given, it was always reversed with protamine.

For upper arm AVG procedures, the brachial artery and axillary vein were exposed through distal and proximal medial upper arm incisions, respectively. Venous and arterial anastomoses were constructed in an end to side fashion. If the outflow vein is stenotic or diseased, we will make every effort to construct the anastomosis proximal to the stenosis. On occasion, a duplicated brachial or axillary vein may serve as a better outflow vessel. The majority of patients were discharged the same day. Patients who were felt to require observation due to co-morbidities or other extenuating circumstances were admitted to the hospital and were discharged on the first postoperative day.

Appendix 2 (online only). Life table estimates of primary patency rates

Print data set WORK.A1 group	*Time (months)*	*n*	*Survival distribution function estimate*	*SDF lower 95% confidence limit*	*SDF upper 95% confidence limit*
AVG	0	190	1.00000	.	.
AVG	12	99	0.44295	0.36211	0.52061
AVG	24	54	0.27149	0.19599	0.35235
AVG	36	32	0.21116	0.13990	0.29239
AVG	48	21	0.17737	0.10774	0.26119
AVG	60	7	0.15008	0.07960	0.24141
tAVF	0	168	1.00000	.	.
tAVF	12	50	0.65143	0.57585	0.71689
tAVF	24	25	0.57905	0.49814	0.65157
tAVF	36	15	0.52758	0.43917	0.60839
tAVF	48	8	0.50804	0.41477	0.59385
tAVF	60	4	0.47300	0.36329	0.57491

AVG, Arteriovenous grafts; *SDF,* survival distribution function; *tAVF,* transposed arteriovenous fistulas.

Appendix 3 (online only). Life table estimates of secondary patency rates

Print data set WORK.A1 group	*Time (months)*	*n*	*Survival distribution function estimate*	*SDF lower 95% confidence limit*	*SDF upper 95% confidence limit*
AVG	0	190	1.00000	.	.
AVG	12	110	0.67832	0.59504	0.74812
AVG	24	59	0.41428	0.32535	0.50079
AVG	36	34	0.28219	0.19794	0.37225
AVG	48	22	0.24994	0.16677	0.34187
AVG	60	8	0.19732	0.11233	0.29978
tAVF	0	165	1.00000	.	.
tAVF	12	82	0.71920	0.64618	0.77973
tAVF	24	38	0.63884	0.55795	0.70884
tAVF	36	20	0.58615	0.49601	0.66567
tAVF	48	13	0.56559	0.46939	0.65089
tAVF	60	4	0.56559	0.46939	0.65089

AVG, Arteriovenous grafts; *SDF,* survival distribution function; *tAVF,* transposed arteriovenous fistulas.